FOSSIL BONES OF HOOKER'S SEA LIONS IN NEW ZEALAND CAVES

T.H. WORTHY

43 The Ridgeway, Nelson, New Zealand.

(Received 27 July, 1991; revised and accepted 8 April, 1992)

ABSTRACT

Worthy, T.H. (1992). Fossil bones of Hooker's sea lions in New Zealand caves. *New Zealand Natural Sciences* 19: 31-39.

Fossil seal bones are recorded from caves, up to 5 km inland, in northwest Nelson, New Zealand. All specifically identifiable bones are sea lion *Phocarctos hookeri*. Most of the fossils appear to have been from male animals. Radiocarbon dating of bone collagen indicates one fossil was about 10 000 years old, and another about 3 000 years old. These dates and the site characteristics for the other fossils suggest most are late glacial to Holocene in age.

KEYWORDS: Fossil - sea lion - caves - Quaternary - New Zealand - *Phocarctos hookeri*.

INTRODUCTION

Four seal species are either common or frequently visit New Zealand shores. The most common, and the only one with breeding populations on the mainland, is the fur seal *Arctocephalus forsteri*. A second otariid, the sea lion *Phocarctos hookeri*, is a regular visitor to southern South Island shores and has its principle breeding colony on the Auckland Islands. The Australian sea lion *Neophoca cinerea* has not been recorded from New Zealand waters. Other pinnipeds recorded from New Zealand are phocids, the leopard seal *Hydrurga leptonyx*, which is a rare visitor, and the southern elephant seal *Mirounga leonina*, which is relatively common in the south and occasionally breeds there.

Pre-Pleistocene fossil bones of seals are relatively rare in New Zealand: the few records are summarised by Fleming (1968) and Fordyce (1982), with one notable addition described by King (1983). They are more common in Holocene dune sites in Northland and in other areas, and occasionally have also been found in swamp sites. For example, bones of a fur seal between 4 700 and 6 900 yr old, were found in a swamp deposit at Turakirae Head in the Wellington area (Mildenhall & Moore 1983), and others at Waikouaiti on the north Otago Coast (bones in Otago Museum). However, in cave deposits they are very rare, unlike fossils of birds which are common in caves throughout New Zealand.

It is therefore of considerable interest to document several occurrences of fossil seals from northwest Nelson cave sites. This study was initiated following the discovery of a fossil seal, in April 1990, during the course of a NZ Speleological Society expedition to explore and document caves around Turimawiwi River, Paturau, northwest Nelson, New Zealand.

This was the third discovery of fossil seal bones from caves at Paturau. Subsequently I have investigated several more caves in the Paturau area finding fossil seal bones in two more sites. The existence of an additional specimen from an unknown cave locality near Takaka and which is now preserved in the Auckland Institute and Museum is also reported here.

The purpose of this contribution is to report on the identity, geological age and significance of these fossils. The recently collected specimens from Turimawiwi, Baby Grand, Creighton's and Wet Neck Caves will be housed in the collection of the National Museum of New Zealand.

DESCRIPTION OF SITES AND SPECIMENS

Fig. 1 depicts the location of the fossil sites.

Turimawiwi River: The entrance to Turimawiwi Cave is located about 45 m a.s.l., metric NZMS 260

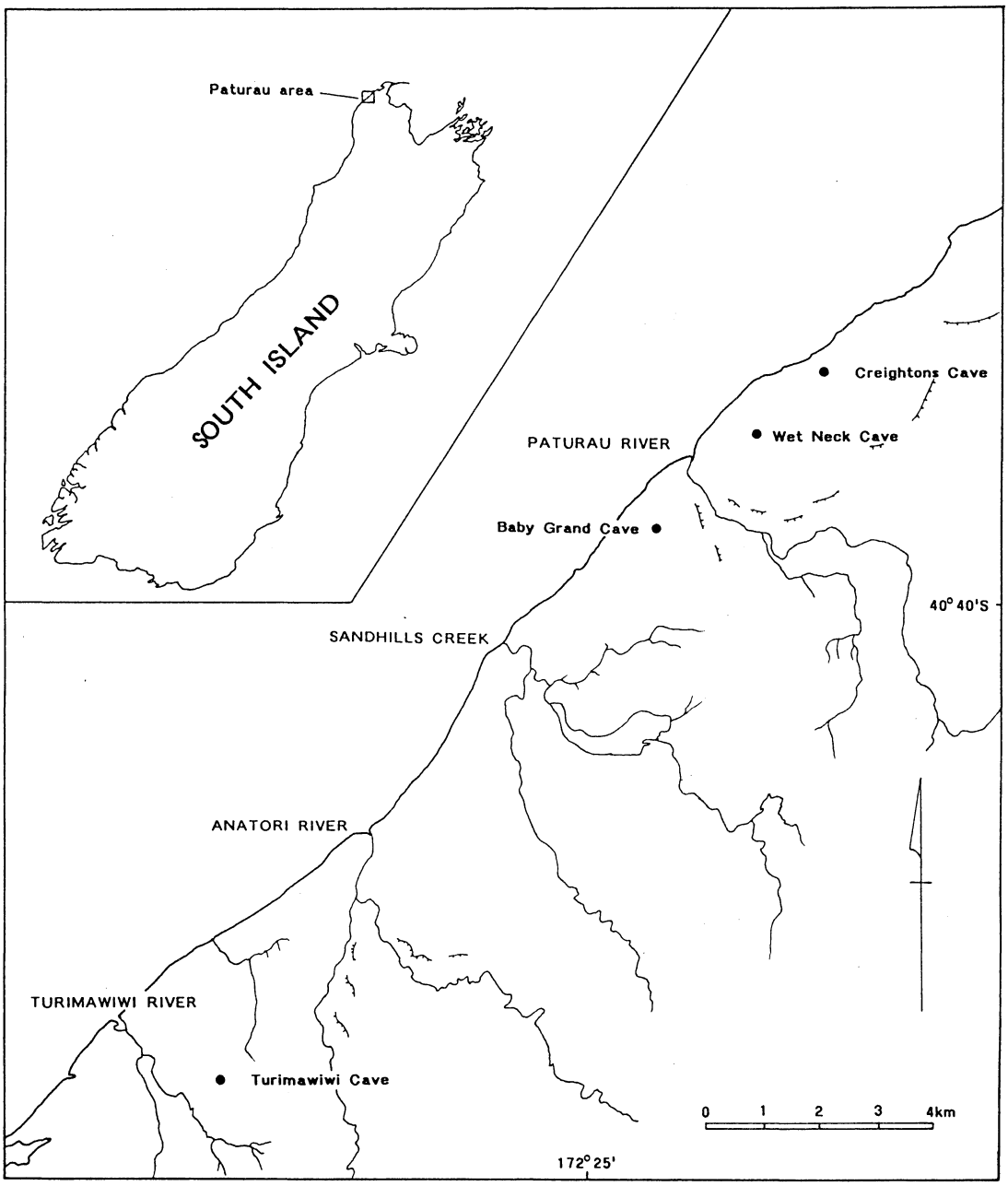

Figure 1. Location map of fossil sea lion sites discussed in the text.

series map M25 gr 5380 5175. Several bones of a seal were found exposed in the base of a vertical wall of stream gravels. I collected the right humerus that was exposed and left the remainder of the bones, ribs and vertebrae, *in situ*. The fossil record number M25/f65 has been allocated for this specimen.

Baby Grand Cave: No. 1. Many fossil bones of a seal skeleton, found in Baby Grand Cave, Paturau in January 1961 (Townsend, 1962: p. 21) were sent

to the Canterbury Museum (CM Ma 725) where they were described by R.J. Scarlett as "not typical fur seal". The main entrance to Baby Grand Cave is about 1 km from the present shoreline (gr M25 6145 6120) and is about 60 m a.s.l. The site within the cave where this fossil was collected is unknown, however the preservation indicates that it was on the cave floor surface, not embedded in stream sediments. Fossil record number M25/f79.

Baby Grand Cave: No. 2. In Easter 1991 I discovered several seal bones in consolidated gravels 6 m above the present stream in the inlet *c.* 120 m east of Baby Entrance which is at the gr M25 6135 6150, fossil record number M25/f80. These bones include an adult left humerus and a smaller juvenile right humerus plus two other unidentified bones thus indicating the presence of at least two individuals.

Wet Neck Cave: An almost complete partially articulated skeleton was found lying on the cave floor in Wet Neck Cave, the main entrance of which has a gr M25 6325 6295, on 8 September 1963 by Ian Townsend and others (Townsend, 1965). The site is 475 m from the nearest entrance which is about 1 km from the coast and about 60 m a.s.l., fossil record number M25/f3. On 15 January 1976 Ian Townsend collected some of the metatarsals (leaving other material *in situ*) for radiocarbon dating. In 1976 the specimen was not identified to species. I visited the site in Easter 1991 and collected several fragments of the skull and a right humerus to add to the tibia, fibula, astragalus of the right leg and one lumbar vertebra collected at my request on 30 December 1990 by B. Sutton and J. Ravens. Because of its late Holocene age, implying deposition when the shoreline was similar to that of the present day, and because it was lying articulated on the cave floor surface I believe this seal travelled the 1 km from the coast, entered the cave, became disoriented, then travelled 450 m upstream to where a rockfall eventually blocked its progress and it died.

Creighton's Cave: During Easter 1991 I visited this cave and located a right humerus, left radius and partial right scapula in the stream bed where they were associated with moa bones. The fossil record number M25/f81 has been allocated to this collection. Creighton's Cave has one known entrance at M25 64356410 but the cave survey indicates a small valley overlies the cave at M25 gr 645 640. Tomos in this valley, at about 60 m a.s.l. and 500 m from the present shoreline, are the probable source of fossil bones in the Creighton's Cave streamway.

Cave at Takaka: In the Auckland Institute and Museum there is a cranium and mandibles of a large male sea lion that was presented by Mr B. Feary of Takaka on 29 February, 1944. It was described as having been found in a limestone cave, but as there are several outcrops of limestone around Takaka, this does not localise the fossil very precisely. The most extensive outcrop, and also that closest to the present shoreline, is at Tarakohe about 8 km northeast of Takaka. In the absence of adequate locality data a fossil record number has not been allocated for this specimen.

OSTEOLOGICAL CHARACTERS OF OTARIID POSTCRANIAL BONES EXAMINED

Most osteological studies of otariids are concerned primarily with cranial morphology, for example King (1960, 1983) and Tedford (1976). The most comprehensive study of otariid seals is that of Repenning and Tedford (1977) who diagnosed the subfamily Arctocephalinae (fur seals) from the Otariinae (sea lions) using a variety of characters. However, only one postcranial osteological character was given and this concerned the humerus: fur seals were considered to have more elongate humeri with a pectoral crest which terminates distally toward the medial lip of the trochlea in contrast to sea lions which have stout humeri in which the pectoral crest is directed toward the midpoint of the distal articulation. More recently Beentjes (1989) compared selected metrical morphological measurements of postcranial bones of *Arctocephalus forsteri* and *Phocarctos hookeri* with univariate and multivariate statistical analyses. No attempt was made to describe shape character differences and only minor quantitative differences were found in some of the limb bone and vertebrae linear dimensions. No statistical difference in the relative humerus length/diameter relationship was found therefore Beentjes expressed doubt as to the utility of this character as a diagnostic indicator as was suggested by Repenning and Tedford (1977). However, Beentjes (1989) confirmed the utility of the orientation of the pectoral (deltoid) crest as a diagnostic character.

Because shape characters in bones are not easily measured an apparent similarity of form as determined by measurements can often mask specific differences in form. For example, the early confusion of moa systematists was due largely to their reliance on measurement data but as Worthy (1988, 1992) has shown a wealth of character states nevertheless are present which define most taxa independent of mensural data. With this in mind, fur seal and sea lion skeletal elements, represented in fossil material, were re-examined for differences.

The humerus was the best preserved and most frequently occurring element among the fossil material, probably because of its relative size and robustness. Bones from the following specimens in the National Museum of New Zealand (NMNZ), Anthropology Department, Otago University (FA) and the Canterbury Museum (CM) were used as reference material to facilitate identification of these fossils: Hooker's sea lion *Phocarctos hookeri* NMNZ 1689, FA23, plus unregistered material from the Anthropology Department, Otago University; fur seal *Arctocephalus forsteri* NMNZ 1640, CM Ma 1092, 1915, 1930, 3084; leopard seal *Hydrurga leptonyx* NMNZ 1344. All fossil humeri were similar to those of otariids (Fig. 2) but very distinct from that of the leopard seal, a phocid, reflecting the marked differences between these families. From my observations, I determined that humeri of otariids differ from each other as follows:

1. In posterolateral view the distal lateral ridge in sea lions is robust and rounded in section, but is distinctly compressed to form a narrow flange in fur seals (Fig. 2Fd).

2. In lateral aspect this crest subsumes into the posterior side of the shaft resulting in a twisted appearance in fur seal humeri (Fig. 2Fc), whereas in sea lions this crest grades evenly into the shaft in a proximal direction with no posterior trend and therefore no twisted appearance.

3. The tuberculum majus (tm) (= pectoral crest) tends to be evenly rounded over the dorsal surface along its whole length in sea lions, whereas in fur seal humeri it is flattened and tends to form a distinct edge along its length.

4. The distal end of the tuberculum majus arises from the shaft in a robust ridge whose medial and lateral surfaces converge dorsally in sea lion humeri. In the fur seal humeri examined these medial and lateral surfaces are more nearly parallel and the ridge they enclose is more compressed.

5. In fur seals the widest point of the distal end was found to be usually level with the symphysis of the condylus humeri and the shaft, but in sea lions this point is more anterior than this symphysis (Fig. 2Ea).

6. In fur seals the tuberculum majus subsumes into the shaft closer to the medial lip of the trochlea, rather than toward the midpoint of the distal articulation, as Repenning and Tedford (1977) noted.

7. Width of sea lion humeri, viewed laterally, is not constricted anterior of the mid-length point, but is markedly so in fur seals at the point marked (Fig. 2Cb).

A tibio-fibula from the Wet Neck specimen was collected and compared to the reference specimens. From my observations of examined collection specimens, tibiae of Hooker's sea lions differ from those of New Zealand fur seals as follows: the condylus lateralis is markedly concave latero-medially and flat antero-posteriorly in fur seals, but is not markedly concave latero-medially and is distinctly convex antero-posteriorly in sea lions; the posterior border between the condylus lateralis and the condylus medialis usually has a deep narrow intervening channel whose sides do not diverge markedly in fur seals, but this channel is broad with sides that diverge widely in sea lions; in fur seals, the antero-posterior depth of the condylus lateralis and its total surface area are distinctly greater than that of the condylus medialis, whereas these values are more nearly the same in sea lions.

An astragalus was present among the bones of two of the fossil specimens. Hooker's sea lion and New Zealand fur seal astragali examined among recent collection specimens are similar in shape. However, those of sea lions differ by being larger and having a well developed foramen completely penetrating them. On adult fur seal astragali there are pits at the site of this foramen indicating that it is open in juveniles but ossifies over with adulthood.

IDENTIFICATION

1. Turimawiwi M25/f65. The humerus from Turimawiwi has preserved remnants of the tuberculum

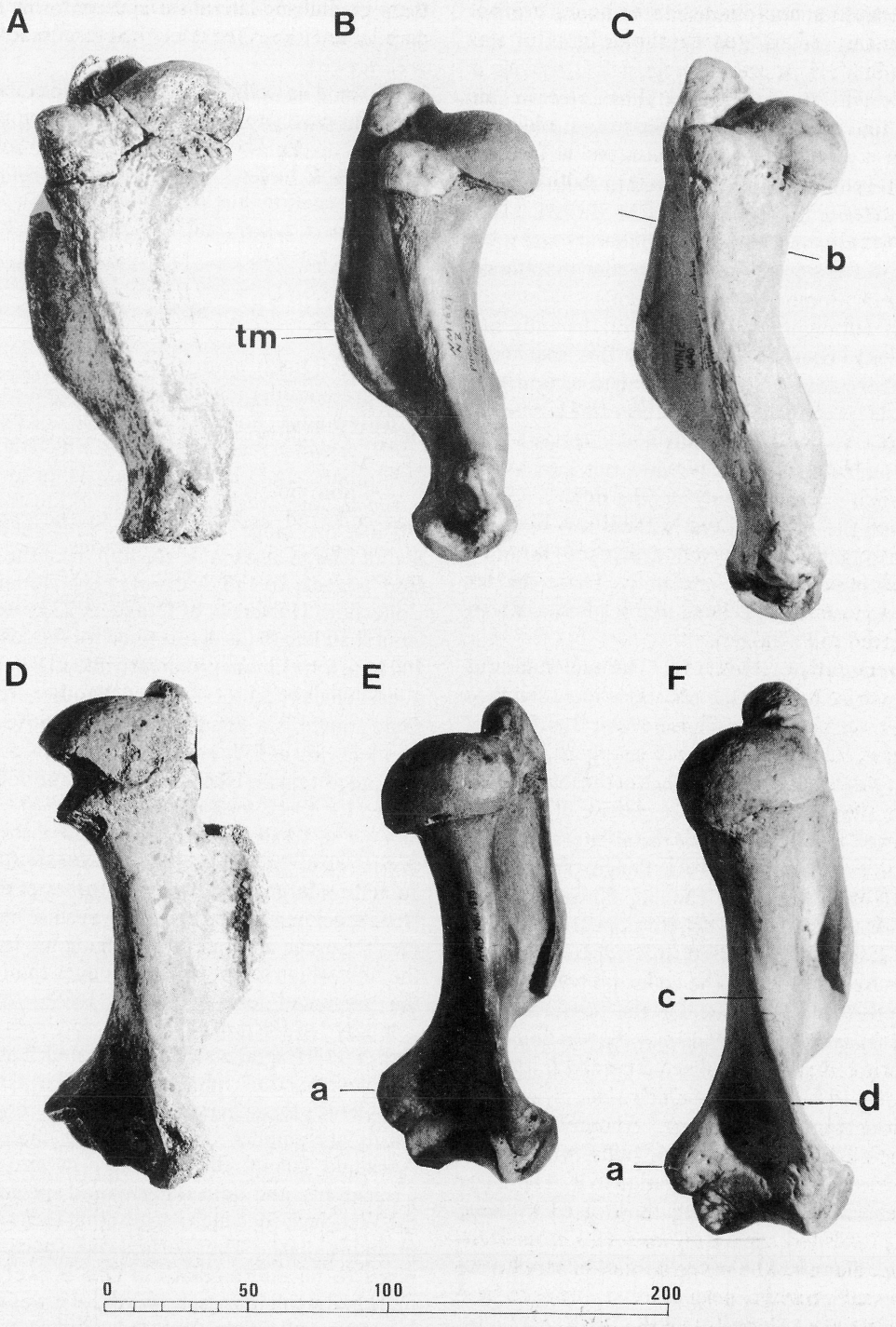

Figure 2. The Turimawiwi fossil seal humerus (A,D) compared to right humeri of Hooker's sea lion *Phocarctos hookeri* NMNZ 1689 (B,E) and fur seal *Arctocephalus forsteri* NMNZ 1640 (C,F) in medial (top) and posterolateral (lower) aspects. Scale bar in mm.

majus which show a rounded dorso-lateral profile. Distally the medial and lateral surfaces of the tuberculum majus are convergent and enclose a robust ridge. The lateral distal ridge is robust and grades into that descending from the anterior end without a twist. These are characteristics of sea lions and so this fossil is referred to *P. hookeri.*

2. Baby Grand No. 1 M25/f79, CM Ma 725. Most bones of this specimen are fragmentary and non-diagnostic material such as rib and metatarsal fragments dominate the collection. However humeri, although much abraded on the ends, are sufficiently complete to identify this specimen. The tuberculum majus has a rounded section over its whole length and its supporting ridge has markedly convergent sides distally and is robust. The distal lateral ridge is not drawn out into a thin flange and it grades evenly into the ridge descending from the proximal end without any twisting. The astragalus has a well developed foramen penetrating the bone completely. These characters diagnose this specimen as a sea lion and so it is referred to *P. hookeri.*

3. Baby Grand No. 2 M25/f80. The adult humerus among these bones is the only bone identifiable to species. Distally the medial and lateral surfaces of the tuberculum majus are convergent about a robust ridge. The dorsal surface of the tuberculum majus, although eroded, is suggestive of it having been well rounded and the distal lateral ridge is robust, not flattened into a flange, and grades directly into the ridge running down from the anterior end without a twisted appearance. This fossil is therefore referred to *P. hookeri.*

4. Wet Neck M25/f3. The collected bones of this well preserved fossil include the humerus, tibia and astragalus which all display the sea lion characters noted above. Collected cranial fragments include part of the palate which is deeply concave (approaching 20 mm deep). Another fragment preserved is the left tympanic bulla, which has a cylindrical posterior prolongation to it. These last two characters are among those used by King (1960, 1983) to separate *Phocarctos* from *Neophoca.* Therefore I have no hesitation in referring this specimen to *P. hookeri.*

5. Creighton's M25/f81. All the fossil seal bones from this cave are otariids, rather than phocids, but only the humerus is identifiable to species. The tuberculum majus is eroded so its features are not discernible. The distal end is complete and the distal lateral ridge is robust and conforms to the shape of sea lions. Therefore this fossil is referred to *P. hookeri.*

6. Takaka. The well preserved skull and mandibles from the cave site in Takaka Valley are clearly from a sea lion. The palate is deeply concave and the tympanic bullae have a well developed posterior prolongation thus identifying this specimen as *Phocarctos hookeri* and not *Neophoca cinerea* (King 1960, 1983).

SEX

Smith (1985) notes that male Hooker's sea lions are considerably larger than females when sexually mature, however, neither he nor Beentjes (1989) provided measurements to which those for fossil bones could be compared. Data for some bones is therefore provided here to illustrate the possible size range. A humerus, presumed to be that of a large adult male sea lion from the Auckland Islands, in the Anthropology Department Collection, University of Otago, is 233 mm long, has a shaft length (as determined for the fossils) of 160 mm, a maximum proximal width of 87 mm and a least shaft width of 40 mm. Another from the same source is a female and comparative measurements are as follows: 181, 122, 66, 29 mm. The presumed female NMNZ 1689 has the following values for these measurements: 172, 109, 63, 27 mm. The fossil humeri are all quite stout and compared to the above bones are apparently from animals of large size (Table 1). Bones of the Wet Neck specimen are the best preserved. This specimen's size can also be assessed from the length of the tibia which is considerably longer than that of the presumed female NMNZ 1689; 235 mm compared to 188 mm. This large size is associated with cranial fragments that display such features as well developed occipital crests and large canines that identify this specimen as a male. Although the fossils are smaller than the larger males from Auckland Island, the similarity in size of the Creighton's, and both Baby Grand specimens to the Wet Neck specimen suggest that these are also probably male. The Turimawiwi specimen appears to be intermediate in size between large male and small female, however, as it was from an immature specimen (unfused condyles), at this size it is also likely to be a male. The Takaka fossils are in good condition: size, well developed occipital crests and large size of canines identify this as from a male.

Table 1. Selected measurements comparing the fossil humeri. Due to the preservation of the fossils it was most practical to make only the three measurements presented here, and then, only to the nearest mm. Length is not total length; it is measured from the medial point of the symphysis of the shaft and the condylus humeri along the shaft to the symphysis with the distal condyle. Values are in mm.

	Creighton's Cave	Wet Neck Cave	Baby Grand Cave No. 1	Baby Grand Cave No. 2	Turimawiwi Cave
Length (A)	-	140	*c.* 140	*c.* 125	134
Max. prox width (B)	-	-	-	-	74
Least shaft width (C)	34	34	34	33	31

AGE

The Turimawiwi fossil was radiocarbon dated by the Nuclear Sciences Group, DSIR using the Accelerator Mass Spectrometry technique. Dating was carried on a sample cored from the shaft region (NZA 1350, R11981) and for which a conventional radiocarbon age (Libby $T_{½}$ 5 568 yr) of 10 260 ± 170 yr BP was obtained.

The date for the Wet Neck specimen (R5330, NZ4297), recalculated from the original data, was 2 980 ± 260 yr BP (radiocarbon age using the NZ Marine Flesh correction), or 3 180 ± 260 yr BP (conventional radiocarbon age).

The Baby Grand specimens are undated but the specimens I collected from consolidated gravels (No. 2) probably date from a significant sedimentation phase in the cave's history. It may therefore be of similar age to the Turimawiwi fossil. The Canterbury Museum specimen (No. 1) comprises many bones of a single skeleton that was found on the cave floor surface and is therefore likely to be more recent because such bones would have been destroyed during the sedimentation phase that occurred about 10 000 years ago. I consider this specimen to be of late Holocene age, *ie.* of similar age to the Wet Neck specimen.

The bones from Creighton's Cave are undated but as they are in the present streambed and exhibit no signs of mineralisation are most likely to be of Holocene age.

DISCUSSION

The geological ages of these specimens are significant for several reasons:

1. The Turimawiwi specimen dates a major sedimentation phase in the caves of the area. The fossil was about 2 m above the present stream level and was overlain by several metres of stream laid gravels. Banks of sediment up to 8 m high remained at sites further down the cave passage and similar banks occur in most other caves in the Paturau area. Therefore the fossil provides a date of 10 260 yr BP for a point in the lower third of this sedimentation event. This date is consistent with those obtained at the Graveyard site in Honeycomb Hill Cave, Oparara (Worthy & Mildenhall 1989). There fossils were deposited in slowly accumulating sediments, between 20 000 and 11 000 yr ago; the youngest date obtained was 10 980 ± 140 yr BP for NZ 7319. Sediments preserved about 10 m from the exposed fossil site in the Graveyard showed that about a further 8 m of sediment were deposited over the fossils in the period immediately following 11 000 yr BP. This period of marked increase in sedimentation coincides with the rapid transformation of the vegetation between 10 500 and 9 500 yr ago which marks the end of the late glacial and the beginning of our present climate (McGlone 1988a). The major vegetation change at this time was that lowland forests became dominated by rimu in most areas of New Zealand. This and other evidence presented by McGlone (1988a) suggests a major increase in rainfall between 11 000 and 9 000 years ago. In northwest Nelson this increased rainfall fell on a steep landscape on which the vegetation was still relatively open contributing to greater erosion and thus sedimentation in caves at lower altitude. It is possible that local tectonic activity also contributed to this sedimentation. The dates for fossils from both Honeycomb Hill Cave and Turimawiwi Cave provide supporting evidence that this sedimentation event commenced about 11 000 yr ago. It probably ceased by 9 000 yr ago

when tall dense vegetation had become established. Supporting evidence that this period of sedimentation ended several thousand years ago is again found in the caves. At the Graveyard site percolation water has had time to develop an entry point to the cave above fossil deposit and, through drip erosion, remove the top 8 m of sediment to expose the fossils. In the Paturau caves the streams have had time to re-erode a route through the infilled gravels to once again flow on the limestone bedrock of the cave floor, leaving only remnants of the sedimentary infills.

2. These finds illustrate how behaviour of an animal affects its potential for entrapment and so fossilisation in caves. It is interesting to note that 10 000 yr ago the sea level was about 30 m lower than it is at present (McGlone 1988b) which, interpreted with the offshore bathometry, means that the entrance to Turimawiwi Cave, presently 1.9 km from the coast, could have been as much as 5 km distant from the coast. Sea lions are known to travel over 1 km inland on subantarctic island (Beentjes 1990) so for one to get into a cave 5 km from the coast is not too unexpected. Similarly, the Baby Grand, Creighton's and Wet Neck sea lions travelled at least 1 km from the coast before becoming lost in the cave. However, such behaviour would be totally foreign to fur seals since these seals usually do not venture more than a few metres from the waters edge (Beentjes 1990). If it is assumed that male and female sea lions would have equal propensity to become entrapped in caves then it is possible that males may have had a greater tendency to roam inland than cows.

3. The fossils described here reveal that Hooker's sea lions were present in the northwest Nelson region at least 10 000 yr ago, and continued to occupy the area until relatively recently. The present range of Hooker's sea lions includes New Zealand's subantarctic islands and southern coasts (Beentjes 1989). Its presence, over 400 km north of Southland, 10 260 yr ago may reflect a northward extension of the sea lions range at that time, which would be consistent with cooler climates known to have occurred then. However, the Wet Neck sea lion, at only 3 000 yr old, and other probable late Holocene records, makes another explanation more likely. Paturau is the only area in New Zealand where extensive karst and caves occur adjacent to the sea coast so providing the best opportunity for sea lions to be trapped in caves. That they were so frequently trapped in the Holocene seems unlikely if the area was only visited by rare northern wanderers as at present. It is also apparent that sea lions were not just restricted to northwest Nelson as their bones are common in fossil dune deposits in the Far North of New Zealand, for example Tokerau Beach (T.H. Worthy, unpubl. data), and are common in early prehistoric archaeological sites throughout the country, *eg.* Spirits Bay, Henderson Bay and Mt Camel in the Far North, Coromandel Peninsula (Smith 1985), Mahia Peninsula (Jeal 1987), and many Southland sites (Smith 1985). Smith (1985) stated "that the sea lions disappeared from the northern North Island by about AD 1 500, and elsewhere they appear to have become very scarce." The implication is that sea lions may have had resident populations in New Zealand and that hunting by Polynesians exterminated these. The remaining population was much reduced and its usual range extended only to southern New Zealand. Then in the nineteenth century hunting by European sealers further reduced the population. Sea lions survived only on the inaccessible southern islands. The fossils reported here support the archaeological data and show that the range of sea lions extended considerably further north in the Holocene. The sea lion can be added to the list of extirpated species alongside the numerous birds of which the moas are the most well known.

ACKNOWLEDGEMENTS

I am indebted to Mrs J.N. Parkinson, who has a long association with the Turimawiwi area, for generously volunteering a considerable monetary sum which enabled the fossil to be dated. I am also indebted to the landowners A. Lowan, H.E. Richards and B. Hart who permitted us to explore the caves on their properties. Ian Townsend kindly made available details of the discovery of the Wet Neck fossil. Dr B. Sutton, J. Ravens, and M. & D. Lipyeat relocated the Wet Neck specimen in the cave and collected some bones. Rowley Taylor helped with information concerning the date of this specimen and habits of seal in general. Roger Sparks (Institute of Nuclear Sciences) provided a reanalysis of the original

radiocarbon data. A.L. Van Heldon, National Museum of New Zealand and Ian Barber, Anthropology Department Otago University, kindly loaned the reference skeletal material used to identify the fossils. Dr B. Gill kindly brought to my attention the existence of the Takaka specimen in the Auckland Institute and Museum. M.S. McGlone kindly commented on the text providing useful comment on palaeoclimate as interpreted from the pollen record, and I thank R.E. Fordyce and M.P. Beentjes for their constructive comments as referees of this manuscript.

REFERENCES

Beentjes, M.P. (1989). Evolutionary ecology of the New Zealand fur seal (*Arctocephalus forsteri*) and Hooker's sea lion (*Phocarctos hookeri*). Unpublished PhD Thesis, University of Otago, New Zealand.

Beentjes, M.P. (1990). Comparative terrestrial locomotion of the Hooker's sea lion (*Phocarctos hookeri*) and the New Zealand fur seal (*Arctocephalus forsteri*): evolutionary and ecological implications. *Zoological Journal of the Linnean Society* 98: 307-325.

Fleming, C.A. (1968). New Zealand fossil seals. *New Zealand Journal of Geology and Geophysics* 11: 1184-1202.

Fordyce, R.E. (1982). The fossil vertebrate record of New Zealand. In *The Fossil Vertebrate Record of Australasia* (ed. P.V. Rich & E.M. Thompson), pp. 630-698. Monash University, Australia.

Jeal, M. (1987). A Mahia Peninsular sea mammal butchery site (N127/14). *New Zealand Archaeological Association Newsletter* 30: 174-175.

King, J.E. (1960). Sea-lions of the genera *Neophoca* and *Phocarctos*. *Mammalia* 24: 445-456.

King, J.E. (1983). The Ohope skull - a new species of Pleistocene sea lion from New Zealand. *New Zealand Journal of Marine and Freshwater Research* 17: 105-120.

McGlone, M.S. (1988a). New Zealand. In *Vegetation History* (ed. B. Huntley & T. Webb III), pp. 557-599. Kluwer Academic Publishers.

McGlone, M.S. (1988b). Post glacial New Zealand. In *Prehistoric New Zealand* (ed. G. Stevens, M. McGlone & B. McCulloch), pp. 92-96, 201-209. Heinemann Reed, Auckland.

Mildenhall, D.C. & Moore, P.R. (1983). A late Holocene pollen sequence at Turakirae Head, and climatic and vegetational changes in the Wellington area in the last 10 000 years. *New Zealand Journal of Science* 26: 447-459.

Repenning, C.A. & Tedford, R.H. (1977). Otarid seals of the Neogene. *Geological Survey Professional Paper 992.* 93 pp.

Smith, I.W.G. (1985). Sea mammal hunting and prehistoric subsistence in New Zealand. Unpublished PhD Thesis, University of Otago, New Zealand.

Tedford, R.H. (1976). Relationships of pinnipeds to other carnivores (Mammalia). *Systematic Zoology* 25: 363-374.

Townsend, I. (1962). Biological records of the Nelson Speleological Group. *Records of the Nelson Speleological Group* 1: 21-26.

Townsend, I. (1965). Wet Neck Cave. *Records of the Nelson Speleological Group* 3: 16-21.

Worthy, T.H. (1988). An illustrated key to the main leg bones of moas (Aves - Dinornithiformes). *National Museum of New Zealand Miscellaneous Series Number 17*, 37 pp.

Worthy, T.H. (1992). A re-examination of the species *Euryapteryx geranoides* (Owen) including comparisons with other emeiin moas (Aves: Dinornithiformes). *Journal of the Royal Society of New Zealand* 22: 19-40.

Worthy, T.H. & Mildenhall, D. C. (1989). A late Otiran-Holocene paleoenvironment reconstruction based on cave excavations in northwest Nelson, New Zealand. *New Zealand Journal of Geology and Geophysics* 32: 243-253.